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The Determination of Lung Function Using Impulse Oscillometry and Spirometry

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THE DETERMINATION OF LUNG FUNCTION USING

IMPULSE OSCILLOMETRY AND SPIROMETY

by

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(Under the Direction of James McMillan)

ABSTRACT

This study was designed to establish normative data for individuals 18-22 years old using oscillometry by comparing the values to spirometry. Oscillometry is a less invasive procedure for respiratory testing than spirometry testing. One hundred and forty-two participants completed self-assessment questionnaires, along with body composition measurements and at least three trials each of oscillometry and spirometry testing. The results of the study conclude that no normative data could be established in this study over all resistance (R) and reactance (X) frequencies for males and females. The secondary goal of this study was to examine the effects of smoking, physical activity, and weight on forced expiratory volume (FEV_1). Smoking and weight had a significant effect on FEV_1 while there was no significance to physical activity and FEV_1 but a trend was found. In conclusion, more testing needs to be conducted to create normative data for 18-22 year olds. This will assist professionals in diagnosing respiratory disorders in this age bracket.

INDEX TERMS: Oscillometry, Spirometry, Lung function, Resistance, Reactance

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DEDICATION

This paper is dedicated to those who have changed careers multiple times and are still trying to find themselves. It is possible to find your way. Keep searching, but have fun while doing so, and never forget the lessons learned and people that cross your path on your journey. To all of the constant procrastinators, one day we will learn to do things early or on time, and when we do, we will have a masterpiece.

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Thank you all!!

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Introduction

Healthy lung function is essential to having a productive and healthy life. Complications or distress within lung structures may cause illnesses and diseases in individuals. In addition to diseases and illnesses, respiratory performance can be attributed to age-related system changes. As people age, there is a decrease in respiratory function (Amara, Koval, Paterson and Cunningham, 2001). With increasing age comes airway closure at higher lung volumes causing expiratory flow limitations and weaker respiratory muscles. Smoking, lack of physical activity, obesity, and chest wall adiposity also affect respiratory function (Amara et al, 2001). Accurate assessment of pulmonary function is essential to evaluate the effect of these factors and natural life occurrences, on lung function.

Assessing pulmonary function has gained greater attention and has been utilized more over the past 15 years in diagnosing individuals with respiratory illness and disease. Over the years, research has lead to improvements in the methods, technology, and knowledge in the assessments of pulmonary function. The different methods for testing pulmonary function include body plethysmography, spirometric testing, forced oscillometry (FO) and impulse oscillometry (IOS). Each method has its own advantages and disadvantages. The “gold standard” for pulmonary testing is spirometry (Kim, Kim, Park and Hong, 2001). Spirometric testing has been shown to be valid, reliable, and reproducible (Kim et al, 2001). Spirometric testing requires total cooperation and forced maximal efforts, which are needed for an accurate test result, and this may be difficult to obtain in all populations (effort dependent) causing an extreme disadvantage to spirometric testing (Kim et al, 2001).

Another method, which is becoming more commonly used and accepted in the medical and clinical community, is oscillometry. DuBois first derived this new method in 1956 (Rozen, Bracamonte and Sergysels, 1983; Neild, Twort, Chinn, McCormack, Jones, Burney, and Cameron, 1989). Advantages to using oscillometry include its non-invasive nature passive cooperation from patients (effort independent) (Kim et al, 2001). IOS/FO has been shown to be easy to use in all populations especially with children, the elderly, and the disabled (Marotta, Klinnert, Price Larsen and Liu, 2003). Oscillometry has steadily become more utilized and accepted in clinical settings and medicine. While there appear to be many advantages to oscillometry, no normal reference standards have been established for all ages.

Reference values for the pulmonary function test (PFT) including spirometry and oscillometry, are used for screening patients for pulmonary diseases and to follow up on their continued progress or regression (Nysom, Ulrik, Hesse and Dirken, 1997). Spirometric testing assess pulmonary function airway obstruction by measuring the forced expiratory volume at one second (FEV_1). This is the amount of air that can be forcibly expelled from the lungs in one second after maximal inspiration. If an individual's FEV_1 is less than 80% this may indicate risk factors for cardiopulmonary disease (CPD), stroke, or lung cancer and may also be an indicator for other risks, such as, obesity and physical inactivity (Jakes, Day, Patel, Khaw, Oakes, and Luben, 2002). Different reference values are used for pediatric ages (persons 18 years and younger) than for adults (persons over 18 years old). There has been no baseline PFT data collected for cohorts between the ages of 18-22 years old and therefore no normative values for these age ranges have not been established. The importance of having normative data is to be able to identify subtle changes in respiratory function at an early age, which empowers the medical community to make well-informed decisions for an individual's health. The aim of this investigation was to establish a normative range of data for 18-22 year olds using IOS/FO and spirometry. Another goal was to examine the effects of gender, ethnicity, smoking, physical activity, height, weight, and body mass index and percentage fat on airway and lung function (FEV_1).

Methods

Participants

Participants in this study were comprised of students between the ages of 18-22 years old from Georgia Southern University's Healthful Living classes. The participants were given an incentive (extra credit towards his/her Healthful Living grade). This make up of participants made for a convenient sampling. Students were in good health with no significant medical history, especially no cardiopulmonary problems. Each student included in the study provided informed consent and was able to perform resting pulmonary function measurements. Those excluded from the study included those who: had significant cardiopulmonary medical histories, were on prescribed lung medications at the time of the study, had a history of TB or congenital lung disease or had a respiratory illness in the last two weeks (sinusitis, pneumonia, upper respiratory infection, asthma exacerbation, flu, or other cardiopulmonary problems). The study attempted to include an equal representation of both genders and all ethnicities. Representation of some groups may be less, due to a smaller percentage of the population density at Georgia Southern University.

Procedure

The Institutional Review Board (IRB) of Georgia Southern University approved the study before the collection of data. Subjects signed an informed consent prior to testing. The informed consent stated the purpose of the study and granted permission to use information gathered in the study. Data was recorded such that using the prefix GSU and the last five digits of his/her Eagle ID could not individually identify subjects. The study was conducted using three parts: participant completion of the self-assessment questionnaire, followed by body composition testing, and finally oscillometry and spirometry testing.

Self-Assessment Questionnaire

Appropriate selected parts of the American Thoracic Society (ATS) questionnaire (Appendix C) were used to assess respiratory, medical wellness, as well as tobacco usage. In addition, the Standard Health Activity Questionnaire (Appendix D) was utilized to assess prior exercise history. The ATS Questionnaire consisted of 52 questions with multiple parts and the Standard Health Activity Questionnaire consisted of 66 questions with multiple parts. These questionnaires have been established as valid and reliable (Larson, Convey, Berry, Wirtz, and Kin, 1993; Wareham, Jakes, Rennie, Mitchell, Hennings, and Day, 2002). The average time needed to complete the questionnaires did not exceed 15 minutes.

Body Composition

Weight was measured using a calibrated medical scale. Standing height was taken, with shoes removed, using a stadiometer. Seated height was also obtained when the subject was in a seated position with measurements taken using a meter ruler that was attached to the wall. Next, three-site skinfold measurements were obtained using a standard protocol (Jackson and Pollack, 1978). The males' sites were the pectoral, abdominal and front thigh areas and the females' sites were the tricep, supra-iliac and front thigh areas all performed on the right side of the body. Skinfold measurement was used to estimate percentage of body fat according to the regression equations used by Jackson and Pollock (1978) and Jackson et al (1980). Standard waist-to-hip measurements were recorded using a tape measure.

Oscillometry

Oscillometry was performed using the Jaeger Oscillometer (Jaeger Instruments, Germany). Oscillometry consists of the subject breathing at rest through a valve. He/she sat with his/her mouth around the valve, and hands resting on his/her cheeks while breathing normally through the valve. The subject was allowed approximately 15 to 30 seconds to stabilize his/her breathing pattern on the valve. The technician visually inspected the presented tidal volume waveforms for stability. Once stability was established, the testing proceeded. The participant continued resting breathing during testing for a run of approximately one minute of while oscillatory recordings were obtained. After each run was completed, the participant performed quiet breathing for 90 seconds before beginning the next test. Once the test was completed, the IOS device performed a “koherenz” calculation to check for acceptability of the data (American Thoracic Society, 1995). The ideal value is 1.0 for perfect data. For this project, acceptable data were values greater than 0.8 at 10 hertz (Hz). Measurements that passed the quality test were recorded in raw form, and a preliminary analysis was performed. Three acceptable oscillometry trials, separated by a minute and a half of quiet breathing, were performed.

Spirometry

Spirograms were performed using a pneumotach (Jaeger Instruments, Germany) coupled to a personal computer. The first step to spirometry testing was the participant began breathing at rest through a valve. After the participant stabilized his/her breathing, he/she inhaled forcefully and exhaled with maximum force for as long as possible, then returned to a normal, resting breathing state. The participant performed quiet breathing for 90 seconds between each run. The participant's airflow volume loops were visually inspected for acceptance using established ATS criteria (American Thoracic Society, 1995). An 80% or greater FEV_1 is a standard measurement determined by the ATS. If the results fell outside the acceptance limits, then the test was recorded but was not included in the analysis. The data collected was used in subsequent analyses evaluating the consistency of IOS/FO to spirometry.

Data Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS version 12.0, SPSS, Chicago, IL, USA). Means and standard deviations were calculated for all variables. Gender differences for age, height, body mass, BMI, ethnicity and smoking were explored. The relationship of FEV_1 with age, body mass, BMI, and height was examined using Pearson's correlation coefficient and independent-t tests were used to assess the relationship between FEV_1 and race, gender, physical activity, and smoking. Regression equations were also computed to examine the relationship among age, height, weight and gender on resistance (R) and reactance (X). Significance levels were set at 0.01.

Results

Descriptive statistics of the study participants are summarized in Table 1. Results show that women tended to be slightly younger, weighed less and were shorter with regards to standing height than the men.

Table 1. Anthropometric data of participants

	All participants (n=142)	Males (n=49)	Females (n=93)
Age (years)	20.08±1.33	20.25±1.37	19.99±1.31
Height (m)	1.67±.095	1.75±0.75	1.63±0.07
Body Mass (kg)	70.57±17.61	81.01±18.95	65.24±14.28
BMI	25.02±5.25	25.92±5.57	24.56±5.05

Results pertaining to race and smoking status by gender are summarized in Table 2. Fifty-seven percent of the participants were white compared to only 38.7% being black. The gap between black and white female participants was larger than the gap between black and white males. Approximately 20% more white females and 15% more white males participated than his/her black counterpart. Women were heavier smokers than men. Cigarettes were the most common form of tobacco use, compared to cigars and pipes.

Table 3 summarizes the relationship between FEV_1 and the following factors: body mass, height, physical activity, age, sex, race, and smoking. Pearson correlation coefficients were used to establish significance between the variables body mass, height, and age. A significance was established between FEV_1 and the variables standing height ($p=0.000$) as well as body mass and FEV_1 ($p=0.000$). The study did not show a relationship between FEV_1 and age, BMI and physical activity. When examining various

Table 2. Proportion of gender with ethnicity and smoking status

	All participants (n=142)	Females (n=93)	Males (n=49)
White	57.0%	58.1%	55.1%
Black	38.7%	37.6%	40.8%
Oriental	0.7%	1.1%	4.1%
Other	2.8%	2.2%	0.0%
Cigarettes			
have smoked	21.4%	23.0%	18.4%
currently smoke	13.4%	15.0%	10.2%
Cigars	2.8%	2.2%	4.1%
Pipes	0.7%	0.0%	2.1%

type of physical activity individually with respect to FEV_1, swimming had a significant relationship to FEV_1 ($p=0.039$). Other physical activities such as cycling, boxing, running, or weeding had no relationship with FEV_1. Independent t-tests were used to determine whether FEV_1 is associated with sex, race, and smoking. Results show that no significant relationships exist.

Table 3. Factors affecting FEV1

Pearson's correlation p-values			Independent T-test p-values	
	FEV1			FEV1
Age	0.717		Physical Activity	0.213
Body Mass	0.006*		Race	0.072
BMI	0.176		Sex	0.594
Standing Height	0.000*		Smoking	0.904
Seated Height	0.856			

* significance at 0.01

An examination of the spirometry data shows that 37.5% of males and 62.5% of females had a FEV_1 greater than or equal to 80%. In males the low percentage of 37.5% may not actually reflect males having respiratory problems; it may just reflect the lack of full effort when trying to complete the spirometry testing. An < 80% FEV_1 may be at risk for Chronic Obstructive Pulmonary Disease (COPD) and confirms the presence of airflow limitation. Regression equations were generated using the stepwise method for resistance (R) and reactance (X) at various frequencies or Hz. The predictive equations, provided in Table 4, were created for females for resistance and reactance at R5hz, 10Hz, 15Hz, and 20Hz and for X5Hz, respectively. Height and weight were the variables chosen because they have the most important impact on respiratory function. Only for R5hz were both predictors, weight and height, included in the regression equation. For males, there were not any significant predictors for either resistance (R) or reactance (X) frequencies to include in a regression equation (p=0.514) when using the F-test for regression testing method.

Table 4. Regression equations for females for IOS parameters

R(5hz) = 1.161-0.531ht+0.001wt
R(10hz) = 0.835-0.308ht
R(15hz) = 0.831-0.312ht
R(20hz) = 0.740-0.260ht
X(5hz) = 0.475+0.209ht

*R=resistance, X=reactance, wt=weight, ht=height

Table 5 shows the range of oscillometry testing frequencies of the participants by gender at the various testing frequencies of resistance (R) and reactance (X).

Table 5. Oscillometry frequency readings

Male					Female			
Minimum	Maximum	Mean	Std. Deviation		Minimum	Maximum	Mean	Std. Deviation
0.17	0.61	0.3100	0.0926	R5	0.19	0.90	0.3968	0.1336
0.17	0.52	0.2723	0.078	R10	0.18	0.79	0.3439	0.1125
0.17	0.42	0.2579	0.066	R15	0.15	0.70	0.3335	0.1025
0.15	0.80	0.2623	0.0997	R20	-0.06	0.60	0.3266	0.1037
-0.24	0.00	-0.1019	0.0571	X5	-0.42	0.02	-0.1359	0.0651
-0.16	0.04	-0.0179	0.0416	X10	-0.20	0.04	-0.0276	0.0454
-0.09	0.08	0.0192	0.0398	X15	-0.13	0.12	0.0249	0.0513
-0.05	0.14	0.0560	0.0409	X20	-0.09	0.19	0.0663	0.0579
-0.01	0.19	0.0946	0.0371	X25	-0.12	0.25	0.1076	0.0594
0.05	0.24	0.1490	0.0370	X35	-0.19	0.53	0.1778	0.0713
7.01	23.74	12.5928	4.32	Resonant Frequency	4.49	29.26	13.0662	4.71
0.03	1.37	0.3568	0.3414	AX	0.00	2.73	0.5006	0.4624

Discussion

The aim of this study was to devise a set of normative ranges using IOS testing for individuals 18-22 years old. Normative values are important to clinicians to help assess a patient's condition and better diagnose problems and symptoms using scientific numerical results. Even though predictive equations were created for females for various resistances (R) and reactance (X) frequencies (Table 4), not all frequencies were accounted for, only the equation for R5hz included both weight and height, and no predictive equations were created for males. Therefore, complete normative values could not be established for the group of 18-22 year olds as a whole. Perhaps the small sample of males contributed to the lack of information gained for their group. The weight predictor, even though significant as affecting FEV_1, was not significant when creating regression equations, leaving only height as the significant predicator in the regression equations for females. Furthermore, it is possible that the sample size used for females may not have been sufficiently large enough to make inferences to the population of females 18-22 year olds.

The results do not show a significant correlation between FEV_1 and smoking or age. The participants used in this study were 18-22 year olds, therefore, the female's lungs have just finished maturing and male's lungs are still maturing or have just finished maturing (Gold, Wang, Wypi et al, 1996). This may explain why there was no correlation between FEV_1 and age due to the fact that the participants smoking had not seriously affected his/her lungs enough to decrease FEV_1 in a substantial way. Previous research suggests that there is a negative relationship between age and smoking frequency: as a person ages and his/her amount of smoking increases, his/her FEV_1 decreases (Pelkonen, Notkola, Tukiainen, Tervahauta, Tumilehto, and Nissinen, 2001; Nevill and Holder, 1999; Gold, Wang, Wypij, Speizer, Ware, and Dockery, 1996). The effects of smoking on the respiratory system are detrimental. Smoking residue affects the physiological and mechanical structures of the lungs, not allowing them to function properly. This in turn decreases the $FEV_{1,}$ indicating possible COPD and other fatal diseases. Just a few years of smoking can decrease a person's $FEV_{1,}$ and a lifetime of smoking can do irreversible damage to smoker's lungs. Intermediate bouts of trying to quit smoking may slow down the decline of FEV_1, the damage to the lungs, and the chances of emphysema, chronic bronchitis and other conditions influenced by smoking (Pelkonen, Notkola, Tukiainen et al, 2001; Nevill and Holder, 1999).

Another vital part of conditioning the lungs and respiratory system is physical activity. Physical activity guidelines set by the American College of Sports Medicine/Center for Disease Control (ACSM/CDC) state that "adults should accumulate 30 minutes or more of moderate intensive physical activity on most, preferable all days of the week" to obtain benefits from physical activity (Burke, Carron, and Eys, 2005). For many individuals this may help to increase or preserve an individual's respiratory function. The present study did not show a significant relationship between physical activity and FEV_1 however, there was a trend of increased FEV_1 among individuals who exercised multiple times per week and did various physical activities per week. Physical activity helps to strengthen the respiratory pump. As age increases, physical activity will help to preserve respiratory function and improve quality of life.

This study shows that standing height and body mass are significantly correlated with FEV_1. Height and body mass have an effect on the mechanical functioning of the lungs (Bottai, Pistelli, Di Pede et al, 2002). Excessive fat that is associated with being overweight or obese interferes with the mechanical functioning of the lungs, making it harder for the lungs to work and decreases the amount of air passing through the lungs. A decrease in body mass will help increase an individual's capability to breathe and reduce the amount of work the lungs perform and hence increasing FEV_1.

Scientific research and new technology are instrumental in finding ways to improve quality of life, find cures for diseases, and identify better ways of earlier detection of medical problems. Using IOS as a means of gathering data from respiratory patients during resting breathing instead of using spirometry allows for better patient cooperation, because patients with respiratory difficulties will not have to tax their lungs. The use of IOS testing also yields reliable data which is comparable to the "gold standard" testing of spirometry. Although 18-22 year olds are capable of performing spirometry correctly, using IOS assures that testing each has a probability of testing being accurately and more easily preformed. ISO/FO testing uses resting breathing, therefore, it should be able to be properly completed by individuals with previous or current respiratory illnesses. Not being able to compare collected data to normative values will delay diagnosis and treatment for 18-22 year olds. Therefore, there is still a need for further studies and data collection to provide clinicians with this information.

Reference

Amara, C. E., Koval, J. J, Paterson, D. H., and Cunningham, D. A. 2001. Lung function in older human: the contributions of body composition, physical activity, and smoking. *Annulas of Human Biology*, **28,** 5, 522-536.

American Thoracic Society. 1995. Standardization of spirometry: 1994 update. *American Journal of Respiratory and Critical Care Medicine, **152,*** 1107-1136.

Bottai, M., Pistelli F., Di Pede, F., Carrozzi, L., Baldacci, S., and Matteeli, G. et al. 2002. Longitudinal changes of body mass index, spirometry and diffusion in a general population. *European Respiratory Journal,* **20,** 665-673.

Burke, S. M., Carron, A. V., and Eys, M. A. 2005. Physical activity context and university student's propensity to meet the guidelines Centers for Disease Control and Prevention/American College of Sports of Medicine, *Medical Science Monitor: International Medical Journal of Experimental and Clinical Research,* **11,** 4, CR171-176.

Cheng, Y. J., Macera, C. A., Addy, C. L., Sy, F. S., Wieland, D., and Blair, S. N. 2003. Effects of physical activity on exercise tests and respiratory function. *British Journal of Sports Medicine,* **37,** 521-528.

Gold, D. R., Wang, X., Wypij, D., Speizer, F. E., Ware, J. H. W., and Dockery, D. W. 1996. Effects of cigarette smoking on lung function in adolescent boys and girls. *The New England Journal of Medicine*, **335,** 13, 931-937.

Goldman, M. D., Carter, R., Klein, R., Fitz, G., Carter, B., and Pachucki, P. 2002. Within- and between day variability of respiratory impedance, using impulse oscillometry in adolescent asthmatics. *Pediatric Pulmonary,* **34,** 312-319.

Guerra, S., Sherrill, D. L., Bobadilla, A., Martinez, F. D., and Barbee R. A. 2002. The relation of body mass index to asthma, chronic bronchitis, and emphysema. *Chest*, **122,** 1256-1263.

Hellinckx, J., Cauberghs, M., De Boeck, K., and Demedts, M. 2001. Evaluation of impulse oscillation system: comparison with forced oscillation technique and body plethysmography. *European Respiratory Jounral*, **18,** 564-570.

Houghton, C. M., Woodcock, A. A., Singh, D. 2004. A comparison of plethysmography spirometry, and oscillometry for assessing the pulmonary effects of inhaled iprat-ropium bromide in healthy subjects and patients with asthma. *British Journal of Clinical Pharmacology,* **59,** 2, 152-159.

Jackson, A. S., and Pollock, M. L. 2004. Generalized equations for predicting body density of men.1978. *British Journal of Nutrition,* **91,** 1, 61-168.

Jackson, A. S., Pollock, M. L., and Ward, A. 1980. Generalized equations for predicting body density of women. *Medicine and Science of Sports and Exercise,* **12,** 3, 175-181.

Jakes, R. W., Day, N. E., Patel, B., Khaw, K., Oakes, S., Luben R., and Welch, A. 2002. Physical inactivity is associated with lower forced expiratory volume in 1 second. European prospective investigation into cancer – Norfolk prospective population study. *American Journal of Epidemiology,* **156,** 2, 139-147.

Kim, C. W., Kim, J. S., Park, J. W., and Hong, C-S. 2001. Clinical applications of forced oscillation techniques (FOT) in patients with bronchial asthma. *The Korean Journal of Internal Medicine,* **16,** 2, 80-86.

Klijn, P. H., Oudshoorn, A., van der Ent, C. K., van der Net, J., Kimpen, J. L., and

Helders, P. J. M. 2005. Effects of anaerobic training in children with cystic fibrosis: a randomized controlled study. *Chest*, **125,** 1299-1305.

Larson, J. L., Convery, M. K., Berry, J. K., Witz, S., and Kin, M. J. 1993. Reliablity and validity of the chronic respiratory disease questionnaire, *American Journal of Critical Care and Medicine,* **147**:A350.

Lazarus, R., Gore, C. J., Booth, M., and Owen, N. 1998. Effects of body composition and fat distribution on ventilatory functions in adults. *American Journal of Clinical Nutrition,* **68,** 35-41.

Marotta, A., Klinnert, M. D., Price, M. R., Larsen, G. L., and Liu, A. H. 2003. Impulse oscillometry provides an effective measure of lung dysfunction in 4-year-old children at risk for persistent asthma. *Journal of Allergy and Clinical Immunology,* **112,** 317-322.

McKay, R. T., Levin, L. S., Lockey, J. E. Lemasters, G. K., Medvedovic, M., Papers, D. M., Simpson, S. R., and Rice, R. 1999, Weight change and lung function: implications for workplace surveillance studies. *The Journal of Occupational and Environmental Medicine,* ***41,*** 7, 596-604.

Mohamed, E., I., Maiolo, C., Iacopino, L., Pepe, M., De Daniele, N., and De Lorenzo, A. 2002. The impact of body-weight components on forced spirometry in healthy Italians. *Lung,* **180,** 149-159.

Nield, J. E., Twort, C. H. C., Chinn, S., McCormack, S., Jones, T. D., Burney, P. G. J., and Cameron, I. R. 1989. The repeatability and validity of respiratory resistance measured by the forced oscillation technique. *Respiratory Medicine,* **83,** 111-118.

Nevill, A. M., and Holder, R. L. 1999. Identifying population differences in lung function: results from the Allied Dunbar national fitness survey. *Annals of Human Biology,* **26,** 3, 267-285.

Nysom, K., Ulrik, C. S., Hesse, B., Dirken, A. 1997. Published models and locals data can bridge gap between refernce values of lung function for children and adults. *European Respiratory Journal,* **10,** 1591-1598.

Pasker, H. G., Peeters, M., Genet, P., Clement, J., Nemery, B., and Van de Woestijne, K. P. 1997. Short-term ventilatory effects in workers exposed to fumes containing zinc oxide: comparison of forced oscillation technique with spirometry. *European Respiratory Journal,* **10,** 1523-1529.

Pelkonen, M., Notkola, I-L., Lakka, T., Tukiainen, O., Kivinen, P., and Nissinen, A. 2003. Delaying decline in pulmonary function with physical activity. A 25 year follow-up. *American Journal of Respiratory and Critical Care Medicine,* **168,** 494-499.

Pelkonen, M., Notkola, I-L., Tukiainen, H., Tervahauta, M., Tumilehto, J., and Nissinen, A. 2001. Smoking cessation, decline in pulmonary function and total mortality: a 30 year follow-up study among the Finnish cohorts of the Seven Countries Study. *Thorax,* **56,** 703-707.

Rigau, J., Burgos, F., Hernandez, C., Roca, J., Navajas, D., and Farre, R. 2003. Unsupervised self-testing of airway obstruction by forced oscillation at the patient's home. *European Respiratory Journal,* **22,** 668-671.

Rozen, D., Bracamonte, M., and Sergysels, R. 1983. Comparison between plethysmography and forced oscillation techniques in the assessment of airflow obstruction.

Respiration, **44,** 197-203.

Shiota, S., Katoh, M., Fujii, M., Aoki, S., Matsuoka, R., and Fukuchi, Y. 2005. Predictive equations and the reliability of the impulse oscillatory system in Japanese adult subjects. *Respirology,* **10,** 310-315.

Timonen, K. L., Randell, J. T., Salonen, R. O., and Pekkanen, J. 1997. Short-term variations in oscillatory and spirmetric lung function indices among school children. *European Respiratory Journal,* **10,** 82-87.

Vink, G. R., Arets, H. G. M., van der Lang, J., and van der Ent, C. K. 2003. Impulse oscillometry: a measure for airway obstruction. *Pediatric Pulmonology,* **35,** 214-219.

Wareham, N. J., Jakes, R. W., Rennie, K. L., Mitchell, J., Hennings, S., and Day, N. E. 2002. Validity and repeatability of the EPIC-Norfolk physical activity questionnaire. *International Journal of Epidemiology,* **31**:168-174**.**

Wise, R. A., Enright, P. L., Connett, J. E., Anthonisen, N. R., Kanner, R. E., Lindgren, P., O'hara, P., Owens, G. R., Rand, C. S., and Tashkin, D. P.1998. Effects of weight gain on pulmonary function after smoking cessation in the lung health study. *American Journal of Respiratory and Critical Care Medicine,* **157,** 866-872.

Appendix A

Limitations, Delimitations, and Assumptions

There are several limitations to this study. There was a lack of randomization in the sampling procedure. This was a convenient sample by using only subjects who were in the Georgia Southern Healthful Living Classes. Multiple t-tests were conducted without adjusting for significance for race. Multiple trained individuals conducted body compositions. Although there is a ±3% variance for body fat readings, there could be more of a variance between the results by the different individuals that conducted the skinfold measurements. Subjects participated during his/her availability; hence, weight measurements were not taken at the same time of the day for all participants. Therefore, due diurnal variation, depending on when a person is measured, his/her weight may fluctuate by a few pounds and bias was not reduced.

One of the delimitations of this study consisted of the age factor, since mostly younger subjects of the 18-22 age range were included due to the study design of collecting data from subjects enrolled in the Healthful Living course that is mostly taken by freshmen and sophomores. Another delimitation of this study was that participants needed to be in a particular state of health and have no drug restrictions.

Assumptions for this study were that participants did not eat or drink at least three hours prior to participation, answered the questionnaire fully and honestly, have not been respiratory compromised in the last two weeks, and gave full maximum effort during testing.

Appendix B

Extended Literature Review

The determination of an individual's lung function is affected by multiple variables. Different variables affect lung function, some of which cannot be controlled while others can. Age and height are variables which individuals have no control over. Aging results in higher rates of decline in pulmonary function (Jakes, Day, Patel et al, 2002; Pelkonen, Notkola, Lakka Tukiainen, Kivinen, and Nissinen, 2003). Aging causes a possible loss of the lung elastic recoil, which may cause a premature airway closure and air trapping during forced expiration. Aging is also associated with increased chest wall compliance, and a decreased strength of respiratory muscles, all of which lead to a decrease in pulmonary function (Pelkonen, Notkola, Lakka et al, 2003). Variables that are influenced directly by individual's lifestyle habits and/or exposure include: history of cigarette smoking or smoke exposure, one's level of physical activity, and a person's weight (Bottai, Pistelli, Di Pede et al, 2002; Gold, Wang, Wypij et al, 1996; Wise, Enright, Connett, Anthonisen, Kanner, and Lindgren, 1998). Knowing what variables influence lung function is crucial for the prevention of the deterioration of one's lung function; but another equally crucial aspect is the accurate assessment of lung function. Proper assessment of lung function is extremely vital for persons with obstruction airway diseases (asthma, emphysema, chronic bronchitis and COPD) or those who with restrictive airway disease. The establishment of baseline measurements, diagnosis of respiratory diseases and different therapeutic strategies are all assessed by the use of pulmonary function tests (PFT's) (Vink, Arets, van der Lang and van der Ent, 2003; McKay, Levin, Lockey, Levin, Lockey, Lemasters, Medvedovic, and Papers, 1999).

PFT's provide invaluable information regarding potential change in lung function due to disease and responses to therapies (McKay, Levin, Lockey et al, 1999). PTF's provide information concerning force vital capacity (FVC) and forced expiratory volume (FEV).

The most addictive variable that influences lung function is cigarette smoking or exposure to cigarette smoke. Smoking is a major source of respiratory illness and distress. Individuals' past and current smoking impact lung function in a negative manner if the individual is susceptible (Nevill and Holder, 1999; Wise, Enright, Connett et al, 1998; Gold, Wang, Wypij et al, 1996). Shiota et al demonstrated a distinct difference between smokers and nonsmokers with regard to lung function. Smokers' lungs seem to be inferior to that of nonsmokers (Nevill and Holder, 1999). People who have or currently smoke, present with declining lung function and the rates of decline is accelerated when compared to individuals who have never smoked (Pelkonen, Notkola, Lakka et al, 2003). Continuing to smoke causes persistently greater decline in lung function and leads to progressively worsening respiratory problems and diseases. There was a greater decrease in FEV_1, FVC, and FEV/FVC in smoking subjects that is not seen in nonsmokers (Cheng, Macera, Addy, Sy, Wieland, and Blair, 2003; Shiota, Katoh, Fujii , Aoki, Matsuka, and Fukuchi, 2005). Compared to age gendered nonsmokers, adolescents who smoked more than 15 cigarettes per day compared to nonsmokers exhibited a 4.1% and 3.2% (boys to girls, respectively) reduction of FEF_{25-75} (Gold, Wang, Wypij et al, 1996). There was also a decrease in FEF_{25-75} (3.5% and 3.2% boys to girls respectively) with each pack of cigarettes smoked per day (Gold, Wang, Wypij et al, 1996). Research has demonstrated that children who smoke have higher rates of asthma (14% vs. 10%) and wheezing (65% vs. 50%). When looking at FEV_1 and FVC, the growth rate of adolescents between the ages of 10-18 years old who smoked was 0.76% slower per year for FVC and for FEV_1 the growth rate was 1.09% slower per year than in adolescents who never smoked (Gold, Wang, Wypij et al, 1996). In adolescent boys and girls, just small amounts of cigarette smoking caused similar deficits in levels of both FEV_1/FVC and FEF_{25-75}.

The effect of intermitting quitting of smoking has some controversial findings in different research as to whether or not intermittent quitting is beneficial when it comes to lung function (Pelkonen, Notkola, Lakka et al, 2003). Pelkonen et al using data from the Lung Health Study noted those intermittent quitters do benefit. Pelkonen et al results revealed that people who had quit smoking had a slower decline in $FEV_{0.75}$ than continuous smokers. Continuing smokers lost 9.18% predicted FEV_1 ($p<0.001$) and 7.43% predicted FVC ($p<0.001$) compared with sustained quitters. Other studies demonstrated that a decline in pulmonary function is faster in those who relapse back to smoking rather than continuous smokers. Wise et al research concluded that stopping smoking was shown to slow the decline in lung function. Nevill et al research yielded results, where nonsmokers decreased less in FEV_1 followed by ex-smokers, and smokers. Ex-smokers suffered consistent 4-5% reduction in lung function performance in both FEV_1 and FVC for all age groups. Lazarus et al showed that quitting smoking improved FEV_1 in males by 11 ml and in females by 49 ml compared with continued smoking (Lazarus, Gore, Booth, and Owen, 1998).

Smoking cessation is associated with weight gain (Wise, Enright, Connett et al, 1998). Wise et al conducted a study that examined the effect of cessation of smoking on body weight. He demonstrated a greater decline in FEV_1 in persons who continue to smoke than in persons who quit smoking and gained weight. Continuous smokers have a greater decline in FEV_1 than was seen among continuous quitters with the most weight gain after they quit smoking. The first year of weight gain after smoking cessation has the largest effect on lung function. The constant fluctuation in body weight can lead to improvements or decline in lung function. Weight gain has been significantly associated with falls in both FEV_1 and FVC. A 10% increase in weight is associated with 0.83% predicted fall in FEV1 ($p<0.001$) and a 1.11% predicted fall in FVC ($p<0.001$). FEV_1 annual declines were greater in those who gained the most weight during follow up periods. For every kilogram of weight gained per year, FVC declines approximately 16 ml (McKay, Levin, Lockey et al, 1999). There is a linear negative association between the percentage weight change and the percentage change in FEV_1 and is significant in men and women alike ($p<0.001$). Individuals who gained weight the fastest demonstrated the fastest rate of decline in FEV_1 (Jakes, Day, Patel et al 2002). Obesity impairs lung function in several ways by causing alterations in the pressure-volume characteristics of the thorax, mircoatelectasis from decreased depth of inspiration, and causes an increased pulmonary blood volume from increased plasma volume (Wise, Enright, Connett et al, 1998). Even though weight gain negatively effects pulmonary function, a person would have to gain 60 kilograms to equal the effect that continuous smoking has on FEV_1.

In the first twelve months of smoking cessation 10.2% males and 12.8% females gained weight of more than 10 kilograms. The mean weight increase was about five kilograms during the first year in men and women who quit smoking. After five years of sustained quitting, 33.9% males and 37% females gained more than 10 kilograms, compared to the 5.2% males and 1.4% females who continued smoking and gained more that 10 kilograms (Wise, Enright, Connett et al, 1998). Four and one-tenths percent of men and 4.7% of women who were sustained quitters gained more than 20 kilograms compared with 0.2% and 0.4% in continuous smokers. Reduced energy expenditure and an increase in caloric intake, these are the primary basis for how most weight is gained. There is a subgroup of people who were not able to get the full health benefits of smoking cessation due to excessive weight gain after smoking cessation that there is an effect on lung function. Among the grossly overweight, there seems to be impairment in ventilatory function. In a study that used men, a negative association with ventilatory function and body fat in the central or upper body was shown. The intermediate trends are similar as the body fat proportions increase; there is an association with the decrease of FVC.

When it pertains to the effect of pulmonary function on the sexes, there seems to be stark differences between each. During childhood and adolescents there is a natural rise in lung function, after this period of growth lung function begins to decline (Cheng, Macera, Addy et al, 2003). Lung development is faster and ends earlier in girls as compared to boys. Girls reach maximum lung function between 16-18 years old, whereas, boys' lung function is still increasing and attains maximum pulmonary function until the early 20's (Gold, Wang, Wypij et al, 1996). In conjunction with girls reaching maximum lung function earlier, adolescent girls are currently smoking at a rate similar to boys (Gold, Wang, Wypij et al, 1996). In girls at or beyond the growth peak the change in FVC is 0.85% slower per year, where in boys at the same point (at or beyond growth peak) the change in FVC is 0.23% slower per year compared to nonsmokers. Similarly, the decline in FEV_1 is greater for girls 1.12% slower per year, where for boys the decline is 0.42% slower per year compared to nonsmokers. The ultimate conclusion is that smoking impacts lung function in girls greater than boys, which may mean greater deficits in girls (Lazarus et al, 1998).

In adults, longitudinal studies have shown that men have respiratory function changes that are not seen in women. The reason for this may be that it has been indicated that women have higher lung efficiency, whereas men have more reserve capacity (Cheng, Macera, Addy et al, 2003). Women also have initial lower FEV_1 and FVC values than men, but the FEV_1/FVC ratio percentage is higher in women than men (Cheng, Macera, Addy et al, 2003; Mohamed, Maiolo, Iacopino, Pepe, De Daniele, and De Lorenzno, 2002). Smoking, weight gain and/or body mass index (BMI) effects the lungs of females differently than males (Cheng, Macera, Addy et al, 2003). Concerning smoking habits, Wise et al concluded across all smoking categories men showed a significantly greater loss of FEV_1 and FVC than women. Women who smoke seem to have a higher prevalence of airway hyperresponsiveness than men, and it could possibly be explained by a lower airway caliber in women.

A risk factor that is seen mostly in women is the association between obesity and asthma, especially if BMI is greater than or equal to 28, there is an increase in the risk of acquiring asthma, especially if the patient is obese before and after the asthma onset (Guerra, Sherrill, Bodadilla, Martinez, and Barbbe, 2002). Women who gained weight after 18 years old were more likely to acquire asthma than males (Guerra et al, 2002). Males and females had different effects when it came to BMI. In males, there is a significant decrease in FEV/FVC and a no significant decrease in FEV/VC. In women the opposite happens (Bottai, Pistelli, Di Pede et al, 2002). As men gain body weight there is a larger reduction in VC. Adult males experience larger losses than females. As weight increases for men, with each 10% increase in weight men lost 1.14% predicted FEV_1 and 1.08% FVC more than women. In both sexes, skinfold thickness has been correlated with pulmonary function, showing a decrease in FVC in association to subcutaneous skinfold thickness. Males have a significantly lower fat mass (FM) and higher fat free mass (FFM) compared to women. (Mohamed, Maiolo, Iacopino et al, 2002). When it comes to physical activity or lack there of, women but not men had a significantly negative association between television watching and FEV_1 (Jakes, Day, Patel et al 2002).

Another component that may greatly affect the quality of one's pulmonary function is BMI or percentage body fat. BMI is not a measurement of body composition, however, typically, increases in BMI are related to increases in body weight and generally body fat. In a study done by Chen et al, it showed how BMI less than 20 in males and BMI greater than or equal to 28 in females increase prevalence of COPD. Guerra et al study revealed that patients with asthma and chronic bronchitis had a significantly higher mean BMI than the control subjects. Even though lung function and its decline are associated primarily with weight gain, lung function decreases at both extremes of weight (McKay, Levin, Lockey et al, 1999). The amount, location, and distribution of body fat can promote and exacerbate many diseases and conditions including CVD, and glucose tolerance. Fat is metabolically active, therefore, fat deposits may have a mechanical effect on the ventilatory function (Bottai, Pistelli, Di Pede et al, 2002; Lazarus, Gore, Booth et al;1998, McKay, Levin, Lockey et al, 1999). The mechanical effect on the diaphragm may impede expansion of the lungs during inspiration, which causes a higher impairment on ventilatory function (Bottai, Pistelli, Di Pede et al, 2002). Ventilatory function requires muscular contraction to overcome air pressure on the large surface area of the chest wall, therefore, the effect body fat has on ventilatory function may be limited to obese individuals (Mohamed, Maiolo, Iacopino et al, 2002). On the other hand, FFM is associated with immune competence, survival and functional status and has no demonstrated or significant relationship to increase in FVC, FEV_1, and PEF (Lazarus, Gore, and Booth et al, 1998; Mohamed, Maiolo, Iacopino et al, 2002). Women and men store fat differently. Men's fat is more centrally located, whereas women's fat is more peripheral (Bottai, Pistelli, Di Pede et al, 2002). There is a significant association between the central pattern of fat distribution and the decrease in ventilatory function in men only when using waist circumference or waist-to-hip ratio measurement (Bottai, Pistelli, Di Pede et al, 2002; McKay, Levin, Lockey et al, 1999; Lazarus, Gore, Booth et al, 1998). Lazarus et al showed there is a significant negative association between percentage body fat and the adjusted FVC. Contradictory to this study, previous studies have shown weak or no significant association with body mass or BMI after accounting for age and height. Cheng et al also concluded that BMI is not associated with respiratory function, but that BMI is associated with lower values of MTT. The results from Mohamed et al suggest that variables age, height, and weight components (BF-LBM, BMC) and not weight and FM correlated significantly with FVC, FEV_1 and PEF ($P<0.0001$) for males and females. Mohamed suggests that even though the effect of body weight is detectable with lung function, additional variables are needed to help explain variance. BF-LBM*height and lung function variables had no significance in weight or height differences between males and females. There was significance when examining the direct effect of muscular mass.

Bottai et al have reported a longitudinal decline of FEV1 and FVC with BMI and body weight gains. BMI's effects on lung function are higher in males, being independent of age. As people lose weight, their lung function starts to improve, and as people gain weight there is a reduction in lung function. Due to the increase in BMI, as individuals become more obese, there is a higher VC loss and decreases in FVC, and FEV. Bottai et al suggests that the effect of gaining weight on the decline of pulmonary function is independent of age, smoking habit, and occupational exposure. By reducing BMI by one unit improves $FEV_{1,}$ 20 ml in males and 16 ml in females. The reduction of BMI improved ventilatory function. On the other hand an increase in BMI from 25 to 35 kg/m^2 shows a decline of 111 and 141 FVC (males and females respectively). Studies by Crapo et al, Stalnecker et al, and Coultae et al have researched the effect of gastric and jejunoileal bypass surgeries on the morbidly obese. These surgeries reported increase in FVC and FEV of 300 ml and 245 ml respectively after surgery. They reported decrease in weight by 40 kg, correlated between weight loss and percentage change in FVC, and declines of FVC, FEV_1, with increases in BMI (McKay, Levin, Lockey et al, 1999).

It is reported that 94 million American's attend college (Burke, Carron and Eys, 2005). As individuals get older their amount of physical activity decreases leading to a tendency of a sedentary lifestyle becomes greater. For individuals to obtain health benefits from physical activity the CDC/ACSM Guidelines state that "adults should accumulate 30 minutes or more of moderate intensity physical activity on most, but preferable all days of the week" (Burke, Carron, and Eys, 2005). In research done by

Burke et al, the results indicated that 42.6% of the participants, who were college students, met CDC/ACSM Guidelines for frequency, intensity and duration. Physical activity is important for increasing muscular strength, improving cardiovascular performance, decreasing obesity, counteracting the stiffening tendency in the chest wall and it promotes longevity (Pelkonen, Notkola, Lakka et al, 2003). Physical activity is a modifiable risk factor that affects pulmonary function, and by participating in the 30 minutes of recommended physical activity health benefits can be gained. Regular exercise and good physical fitness produces better pulmonary function (Pelkonen, Notkola, Lakka et al, 2003). Physical activity may help enhance inspiratory muscle endurance and may be beneficial to smokers and nonsmokers (Cheng, Macera, Addy et al, 2003).

With the guidelines set for positive affects on health benefits, there is a mixed consensus on the effect of physical activity on pulmonary function. Research is split on the effect of pulmonary function and either its potential to increase or slow the declining of FEV_1 and FVC. Research done by Klijn et al using patients with Cystic Fibrosis revealed that values after a follow-up visit with aerobic and anaerobic training groups; physical activity did not change pulmonary function in either group (Klijn, Oudshoorn, van der Ent, van der Net, Kimpen, 2005). On the hand, physical activity has been shown to be positively associated with pulmonary function. Pelkonen et al concluded in two different longitudinal studies that physical activity positively correlated with the level of FVC in 13-27 year olds, and that there was a slower decline in FEV in those who participated in physical activity. Jakes et al concluded that there was a significant positive association between FEV_1 and stair climbing, and the amount of vigorous recreational activity in men and women. The more stair climbing, the greater decline in FEVpercentage. Cheng et al research concluded that with the increase of physical activity levels, there was also an increase in FEV_1 and FVC levels, but there was not a difference in the FEV_1/FVC% ratio. This shows that the association between physical activity and the degree of respiratory obstruction is not supported. Men in the highest physical activity group, had a much slower adjusted decline of $FEV_{0.75}$ and in a year the decline was 9.8 ml per year smaller than individuals in the lowest physical activity group. People with high-energy expenditures, greater than 2,268 kcal per week, demonstrated a slower decline in pulmonary function (Pelkonen, Notkola, Lakka et al, 2003). The results from Jakes et al showed that fitness-inducing aspects of physical activity have an association with respiratory function. Participants who had a MET score of more than five had a slower decline in percentage change FEV_1. Even with physical activity being a modifiable risk factor, smoking is the most modifiable risk factor. The effect of physical activity is not as great as smoking on pulmonary function. The effect of physical activity on the yearly change in $FEV_{0.75}$ is smaller than that of smoking (Pelkonen, Notkola, Tukiainen et al, 2001). However, in individuals who incorporated physical activity into their lives, they showed a slower decline in $FEV_{0.75}$ in all smoking categories.

Participating in physical activity in one's youth is a great way to slow the effects of age on pulmonary function. Individuals who engage in sports have higher levels of pulmonary function than sedentary people. A study that examined the pulmonary function of males and female swimmers concluded that they had larger FEV_1 values than land based athletes or sedentary controls (Cheng, Macera, Addy et al, 2003). Physical activity may delay the decline in pulmonary function in middle or old age. In previous research, it was found that older individuals who are physically active and fit have a better pulmonary function (Pelkonen, Notkola, Tukiainen et al, 2001). Another study examined men over a 25 year period, indicates that men in the highest group of physical activity group lost significantly less $FEV_{0.75}$ and people who had high levels of physical activity or changed their lifestyle to include higher levels of physical activity at a younger age, had a slower decline in $FEV_{0.75}$ and after 20 years they had higher values of $FEV_{0.75}$ (Pelkonen, Notkola, Lakka et al, 2003).

Proper assessments, equipment and techniques are required to make an informed and most importantly an accurate diagnosis for individuals suffering with pulmonary illness and distress. Lung function consists of measuring lung volume and flows. Several different techniques are used to assess lung function; body plethysmography, spirometry and forced oscillometry techniques (FOT). With each technique come its own advantages and limitations when used in pulmonary assessments. The first pulmonary test was introduced by Hutchinson in 1846 and was called spirometry (Lazarus, Gore, Booth et al, 1998; McKay, Levin, Lockey et al, 1999). Hutchinson said about the spirometer that it is a “precise and easy method of detecting disease” (McKay, Levin, Lockey et al, 1999). Spirometry is considered the “gold standard” for assessing lung function and is well documented for assessing, detecting, and measuring lung function and changes (Kim, Kim, Park et al, 2001; Rigau, Burgos, Hernandez, Roca, Navajas, and Farre, 2003, Timonen, Randell, Salonen, and Pekkanen, 1997). Spirometry is commonly used to help assess bronchodilation and measure airway obstruction (Houghton, Woodcock and Singh, 2004; Kim, Kim, Park et al, 2001; Timonen, Randell, Salonen et al, 1997). The limitations that are present with spirometric testing is the difficulty found in getting full cooperation from patients and completing tests especially in children and elderly populations (Rigau, Burgos, Hernandez et al, 2003, Timonen, Randell, Salonen et al, 1997; Houghton, Woodcock, and Singh, 2004; Kim, Kim, Park et al, 2001). For usable and accurate test results, active cooperation and correct breathing techniques are needed. Children tend to finish expirations too early (Timonen, Randell, Salonen et al, 1997). Another limitation to using spirometry is that forced maneuvers may affect bronchomotor tone (Rigau, Burgos, Hernandez et al, 2003; Timonen, Randell, Salonen et al, 1997). Research conducted by Rigau et al compared FOT and Spirometry, the standard deviations was larger in the second and third measurements than in the first, which may suggest that the forced breathing maneuvers may have affected bronchomotor tone, especially in small airways.

Body plethysmography has been shown to measure physiological changes in airway resistance effectively. Research by Houghton et al revealed that the use of body plethysmography an excellent way to measure asthmatics, better than using spirometry or the impulse oscillometry system (IOS) and was also the most optimum technique for assessing pharmacological effects on asthma. Limited variability is a limitation created by using body plethysmography. The more repeated testing done on an individual, the more of a possibility to reduce variability (Houghton, Woodcock, and Singh, 2004). Another limitation with using body plethysmography is the high cost for use, making this technique less utilized by clinicians.

Forced oscillation technique (FOT) was introduced as a technique to correct limitations seen in the two previous lung function assessing techniques. Nearly a century later, another method of assessing pulmonary function was invented by DuBois et al which was the first oscillatory method for measurement of respiratory system mechanics and creating a set of pulmonary mechanical parameters (Goldman, Carter, Klein, Fitz, Carter, and Pachucki, 2002; Kim, Kim, Park et al, 2001). Even though both techniques (spirometry and FOT) require different types of cooperation from the subject, these two methods are important assessment tools for clinicians. Impulse oscillometry (IOS) is a type of FOT (Shiota, Katoh, Fujii et al, 2005). IOS is a way to measure lung function by only needing passive cooperation from a patient (Marotta, Klinnert, Price et al, 2003; Kim, Kim, Park et al, 2001; Pasker, Peeters, Genet et al, 1997). IOS works by applying pulsed pressure flow excitation to the respiratory system and is measured in terms of resistance and reactance (Marotta, Klinnert, Price et al, 2003; Shiota, Katoh, Fujii et al, 2005). Resistance measures the frictional loss occurring during overflow in the bronchus (real). Reactance measures the energy stored by more peripheral components of the respiratory system (imaginary) (Shiota, Katoh, Fujii et al, 2005). The resonant frequency which is measured in hertz (Hz) is when there is no phase shift between pressure and flow signal (Hellinckx, Caugerghs, De Boeck, and Demedts, 2001). The advantage of using IOS over spirometry and body plethysmography is that it can be easily used in populations such as neonates, young children, and the elderly due to requiring only passive cooperation (Kim, Kim, Park et al, 2001; Marotta, Klinnert, Price et al, 2003; Pasker, Peeters, Genet et al, 1997). Tidal breathing is used during IOS, unlike with spirometry; therefore, there is not any possible effect on the bronchomotor tone (Timonen, Randell, Salonen et al, 1997).

Data collected from the different types of techniques are compared to spirometry data. Spirometry data has been shown to be valid, reliable, and reproducible. With respect to comparing FOT to spirometry, previous research revealed there is a correlation between FOT and spirometry (R^2=0.83) (Hellinckx, Cauberghs, and De Boeck et al, 2001). FOT was found to be highly reproducible and compatible with FEV_1. There was also a significant association between FOT parameters with FEV_1 and MMEF. Another study examined the repeatability of FOT and compared its values to MEF_{25} and MMEF, which is know to be a sensitive indicators of airway obstruction. FOT was found to be the most sensitive parameter, which appears to be suitable for the detection of short-term function changes in the respiratory system. Results from Pasker et al revealed that FOT is as sensitive as spirometry in detecting small across-shift changes in ventilatory function. Being that IOS is a type of FOT, IOS is also a valid and reliable source of instrumentation and its data can be compared to FOT data. Previous research with respect to IOS showed that IOS is as reproducible, valid and reliable as spirometry and FOT. Research conducted by Shiota et al had a significantly reproducibility (95% CI within 2 SD). Vink et al concluded that R and X values (resistance and reactance, respectively) when compared with FEV measurements are significantly correlated. R-values correlated better with FEV than X values. R and X values show a significant change during changes in airflow obstruction, this is a significant correlation with FEV_1. Vink et al along with previous studies showed that lower R frequency (5 Hz) is more sensitive to detecting small changes in airflow obstruction and lung function than FEV_1. In studies by both Marotta and Vink et al they concluded that IOS was able to detect significant differences in bronchodilator use in asthmatics at R5 and R10. By using spirometry there was not any significant differences found. IOS is able to detect significant differences between asthmatics and healthy subjects. In healthy individuals respiratory resistance is relatively constant at different frequencies (Houghton, Woodcock, and Singh, 2004). In healthy subjects there was a large variability which may make the use of IOS in healthy subjects a questionable technique for effectiveness (Houghton, Woodcock, and Singh, 2004).

Research has been reported IOS as being an easy procedure to complete by individuals of all ages and lung functionality due to passive cooperation that is need to complete the testing, but there seems to be missing data for individuals between the ages of 18-22 year old. The considerable amount of research that has been done using oscillometry has been in the younger population (ages 3-17), younger individuals who are respiratory compromised, or older adults who are respiratory compromised. There seems to be a lack of information in the research world that is dedicated or includes the generation of individuals between the ages of 18-22. Having a set of normative values for this particular age group will allow clinicians to see if there are trends in lung function between young adults and adults. It may also give information into how early and rapidly lung function may begin to decline once lungs are fully matured, and functioning and how factors such as smoking habits and physical activity contribute to the deterioration of an individual's lung function. To date, there are holes in research utilizing oscillometry when examining person's cigarette smoking habits and levels of physical activity that spirometry has conclusive data regarding. By setting normative data researchers may start taking a more active approach to using oscillometry setting a standard for 18-22 as much as spirometry is a "gold standard".

ATS Questionnaire

4846

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C. Questionnaires

1. Adult Questionnaire

ATS-DLD-78-A

A. ADULT QUESTIONNAIRE — SELF-COMPLETION
(for those 13 years of age and older)

Thank you for your willingness to participate. You were selected by a scientific sampling procedure, and your cooperation is very important to the success of the study.

This is a questionnaire you are asked to fill out. Please answer the questions as frankly and accurately as possible. ALL INFORMATION OBTAINED IN THE STUDY WILL BE KEPT CONFIDENTIAL AND USED FOR MEDICAL RESEARCH ONLY. Your personal physician will be informed about the test results if you desire.

The questions can be answered by checking the best answer or by filling in a blank with a number or word.

Example: Do you live in the United States 1. Yes ✓
2. No ___

If you desire help in answering a question, please put a check (✓) in *front* of the question number. You will be helped with these questions at the time of your appointment.

ALL QUESTIONNAIRES

IDENTIFICATION NUMBER ‾1 ‾2 ‾3 ‾4 ‾5

Card Number $\frac{1}{6}$

NAME: ______________________________

ADDRESS: ______________________________

______________________________ (Zip Code) ‾7 ‾8 ‾9 ‾10 ‾11

TELEPHONE NUMBER: ______________________________

INTERVIEWER: ______________________________ ‾12

DATE: ______________________________ ‾13 ‾14 ‾15 ‾16 ‾17 ‾18
MO DAY YR

		For Office Use
1. Date of Birth: ____________ Month Day Year		(19-24)
2. Place of Birth: ______________________________		(25-26)
3. Sex:	1. Male ________ 2. Female ________	(27)
4. What is your marital status?	1. Single ________ 2. Married ________ 3. Widowed ________ 4. Separated / Divorced ________	(28)
5. Race	1. White ________ 2. Black ________ 3. Oriental ________ 4. Other ________	(29)
6. What is the highest grade completed in school? ____________ *(For example:* 12 years is completion of high school)		(30-31)

For Office Use

EPISODES OF COUGH AND PHLEGM

9A. Have you had periods or episodes of (increased*) cough and phlegm lasting for 3 weeks or more each year? *(For persons who usually have cough and/or phlegm)	1. Yes____ 2. No____	(35)
IF *YES* TO 9A:		
B. For how long have you had at least 1 such episode per year?	______ Number of years 88. Does not apply____	(36-37)

WHEEZING

10A. Does your chest ever sound wheezy or whistling:		
1. When you have a cold?	1. Yes____ 2. No____	(38)
2. Occasionally apart from colds?	1. Yes____ 2. No____	(39)
3. Most days or nights?	1. Yes____ 2. No____	(40)
IF *YES* TO 1, 2, OR 3 IN 10A:		
B. For how many years has this been present?	______ Number of years 88. Does not apply____	(41-42)
11A. Have you ever had an attack of wheezing that has made you feel short of breath?	1. Yes____ 2. No____	(43)
IF *YES* TO 11A:		
B. How old were you when you had your first such attack?	______Age in years 88. Does not apply____	(44-45)
C. Have you had 2 or more such episodes?	1. Yes____ 2. No____ 8. Does not apply____	(46)
D. Have you ever required medicine or treatment for the(se) attack(s)?	1. Yes____ 2. No____ 8. Does not apply____	(47)

For Office Use

2A. Pneumonia (include bronchopneumonia)? 1. Yes_____ 2. No_____ (63)

IF *YES* TO 2A:

B. Was it confirmed by a doctor? 1. Yes_____ 2. No_____ (64)
8. Does not apply_____

C. At what age did you first have it? _____Age in years (65-66)
88. Does not apply_____

3A. Hay fever? 1. Yes_____ 2. No_____ (67)

IF *YES* TO 3A:

B. Was it confirmed by a doctor? 1. Yes_____ 2. No_____ (68)
8. Does not apply_____

C. At what age did it start? _____Age in years (69-70)
88. Does not apply_____

18A. Have you ever had chronic bronchitis? 1. Yes_____ 2. No_____ (71)

IF *YES* TO 18A:

B. Do you still have it? 1. Yes_____ 2. No_____ (72)
8. Does not apply_____

C. Was it confirmed by a doctor? 1. Yes_____ 2. No_____ (73)
8. Does not apply_____

D. At what age did it start? _____Age in years (74-75)
88. Does not apply_____

19A. Have you ever had emphysema? 1. Yes_____ 2. No_____ (76)

IF *YES* TO 19A:

B. Do you still have it? 1. Yes_____ 2. No_____ (77)
8. Does not apply_____

C. Was it confirmed by a doctor? 1. Yes_____ 2. No_____ (78)
8. Does not apply_____

D. At what age did it start? _____Age in years (79-80)
88. Does not apply_____

For Office Use

OCCUPATIONAL HISTORY

24A. Have you ever worked full time (30 hours per week or more) for 6 months or more?	1. Yes____ 2. No____	(21)

IF *YES* TO 24A:

B. Have you ever worked for a year or more in any dusty job?	1. Yes____ 2. No____ 8. Does not apply____	(22)
Specify job/industry ________	Total years worked ____	(23-24)
Was dust exposure: 1. Mild____ 2. Moderate____	3. Severe____?	(25)
C. Have you ever been exposed to gas or chemical fumes in your work?	1. Yes____ 2. No____	(26)
Specify job/industry ________	Total years worked ____	(27-28)
Was exposure: 1. Mild____ 2. Moderate____	3. Severe____?	(29)
D. What has been your usual occupation or job—the one you have worked at the longest?		
1. Job occupation:________		(30-31)
2. Number of years employed in this occupation:________		
3. Position-job title:________		
4. Business, field, or industry:________		

For Office Use

TOBACCO SMOKING

25A. Have you ever smoked cigarettes? (*No* means less than 20 packs of cigarettes or 12 oz of tobacco in a lifetime or less than 1 cigarette a day for 1 year.	1. Yes____ 2. No____	(32)

IF *YES* TO 25A:

B. Do you now smoke cigarettes (as of 1 month ago)?	1. Yes____ 2. No____ 8. Does not apply____	(33)
C. How old were you when you first started regular cigarette smoking?	____Age in years 88. Does not apply____	(34-35)
D. If you have stopped smoking cigarettes completely, how old were you when you stopped?	____Age stopped Check if still smoking ____ 88. Does not apply____	(36-37)
E. How many cigarettes do you smoke per day now?	____Cigarettes per day 88. Does not apply____	(38-39
F. On the average of the entire time you smoked, how many cigarettes did you smoke per day?	____Cigarettes per day 88. Does not apply____	(40-41)
G. Do or did you inhale the cigarette smoke?	1. Does not apply____ 2. Not at all____ 3. Slightly____ 4. Moderately____ 5. Deeply____	(42)

ID Number | | | | | | | |

PHYSICAL ACTIVITY QUESTIONNAIRE

This questionnaire is designed to find out about your physical activity in your everyday life.

Please try to answer every question, except when there is a specific request to skip a section.

Your answers will be treated as strictly confidential and will be used only for medical research

CAMB/PA/4/1201

THE QUESTIONNAIRE IS DIVIDED INTO 3 SECTIONS

- **Section A** asks about your physical activity patterns in and around the house.
- **Section B** is about travel to work and your activity at work.
  It may be skipped by people who have not worked at any stage during the last 12 months.
- **Section C** asks about recreations that you may have engaged in during the last 12 months.

What is your date of birth? __ __ / __ __ / __ __ __ __ (day / month / year)

What is today's date? __ __ / __ __ / __ __ __ __ (day / month / year)

Your sex *(Please tick (✓) appropriate box)*? Male ☐ Female ☐

Section A HOME ACTIVITIES

GETTING UP AND GOING TO BED

*Please put a time in **each** box*

	Average over the past year	
	At what time do you normally get up?	At what time do you normally go to bed?
On a weekday		
On a weekend day		

GETTING ABOUT — Apart from going to work

Which form of transport do you use **most often** apart from your journey to and from work?

*Please tick (✓) one box **ONLY** per line*

Distance of journeys	Usual mode of transport			
	Car	Walk	Public transport	Cycle
less than one mile				
1–5 mile(s)				
More than 5 miles				

TV OR VIDEO VIEWING

*Please put a tick (✓) on **every** line*

Hours of TV or Video watched per day	Average over the last 12 months					
	None	less than 1 hour a day	1 to 2 hours a day	2 to 3 hours a day	3 to 4 hours a day	More than 4 hours a day
On a weekday before 6 pm						
On a weekday after 6 pm						
On a weekend day before 6 pm						
On a weekend day after 6 pm						

STAIR CLIMBING AT HOME

*Please put a tick (✓) on **every** line*

Number of times you climbed up a flight of stairs (approx 10 steps) each day at home	Average over the last 12 months					
	None	1 to 5 times a day	6 to 10 times a day	11 to 15 times a day	16 to 20 times a day	More than 20 times a day
On a weekday						
On a weekend day						

ACTIVITIES IN AND AROUND THE HOME

*Please put a tick (✓) on **every** line*

Approximate number of hours each week	Average over the last 12 months						
	None	Less than 1 hour a week	1 to 3 hours a week	3 to 6 hours a week	6 to 10 hours a week	10 to 15 hours a week	More than 15 hours a week
Preparing food, cooking and washing up							
Shopping for food and groceries							
Shopping and browsing in shops for other items (e.g. clothes,toys)							
Cleaning the house							
Doing the laundry and ironing							
Caring for pre-school children or babies at home (not as paid employment)							
Caring for handicapped, elderly or disabled people at home (not as paid employment)							

Section B ACTIVITY AT WORK

Please answer this section **only** if you have been in paid employment at any time during the last 12 months or you have done regular, organised voluntary work.

If not please go to page 9

TYPES OF WORK DURING THE LAST TWELVE MONTHS

- We would like to know what full or part-time jobs you have done in the last 12 months.
- You may have held a single job or have held two jobs at once.
- If you have changed jobs with the same employer, you should enter it as a change of job **only** if it entailed a substantial change in physical effort.

EXAMPLE

Someone who worked full-time for 6 months, then retired, rested for 3 months and then started a voluntary job for 6 hours a week, would complete the questions as follows.

	Job 1	Job 2
Name of occupation	nurse	shop work
How many hours **per week** did you usually work?	38	6
For how many months in the last 12 months did you do this work?	6	3

ACTIVITY LEVELS AT YOUR WORK

Now we would like you to take the total number of hours you worked per week in each job and divide them up according to your activity level.

Please complete EACH line

	Job 1			Job 2		
	No	Yes	Hours per week	No	Yes	Hours per week
Sitting — light work e.g. desk work, or driving a car or truck		✓	6	✓		
Sitting — moderate work e.g. working heavy levers or riding a mower or forklift truck	✓				✓	2
Standing — light work e.g. lab technician work or working at a shop counter		✓	30		✓	4
Standing — light/moderate work e.g. light welding or stocking shelves		✓	2	✓		

The number of hours in each activity should add up to the number of hours that you worked in each job e.g. 6+30+2=38 (nurse)

What jobs have you held in the last 12 months, and how many months in the year did you do them?

Please complete EACH line

	Job 1	Job 2
Name of occupation		
How many hours **per week** did you usually work?		
For how many months in the last 12 months did you do this work?		

ACTIVITY LEVELS AT YOUR WORK

Now we would like you to take the total number of hours you worked per week in each job and divide them up according to your activity level.

Please complete EACH line

	Job 1			Job 2		
	No	Yes	Hours per week	No	Yes	Hours per week
Sitting — light work e.g. desk work, or driving a car or truck						
Sitting — moderate work e.g. working heavy levers or riding a mower or forklift truck						
Standing — light work e.g. lab technician work or working at a shop counter						
Standing — light/moderate work e.g. light welding or stocking shelves						
Standing — moderate work e.g. fast rate assembly line work or lifting up to 50 lbs every 5 minutes for a few seconds at a time						
Standing — moderate/heavy work e.g. masonry/painting or lifting more than 50 lbs every 5 minutes for a few seconds at a time						
Walking at work — carrying nothing heavier than a briefcase e.g. moving about a shop						
Walking — carrying something heavy						
Moving, pushing heavy objects objects weighing over 75lbs						

STAIR OR STEP CLIMBING AT WORK

Please put a tick (✓) on EACH line where appropriate

Number of times you climbed up a flight of stairs (10 steps) at work	AVERAGE OVER THE LAST 12 MONTHS					
	None	1 to 5 times a day	6 to 10 times a day	11 to 15 times a day	16 to 20 times a day	More than 20 times a day
Job 1						
Job 2						

Please put a tick (✓) on EACH line where appropriate

Number of times you climbed up a ladder at work	AVERAGE OVER THE LAST 12 MONTHS					
	None	1 to 5 times a day	6 to 10 times a day	11 to 15 times a day	16 to 20 times a day	More than 20 times a day
Job 1						
Job 2						

KNEELING AND SQUATTING AT WORK IN JOB 1

In an average working day in Job 1 did you

kneel for more than one hour in total?	No ☐	Yes ☐	Don't know ☐
squat for more than one hour in total?	No ☐	Yes ☐	Don't know ☐
get up from kneeling or squatting more than 30 times?	No ☐	Yes ☐	Don't know ☐

KNEELING AND SQUATTING AT WORK IN JOB 2

In an average working day in Job 2 did you

kneel for more than one hour in total?	No ☐	Yes ☐	Don't know ☐
squat for more than one hour in total?	No ☐	Yes ☐	Don't know ☐
get up from kneeling or squatting more than 30 times?	No ☐	Yes ☐	Don't know ☐

TRAVEL TO AND FROM WORK

JOB 1

Please complete EVERY line

Roughly how many miles was it from home to Job 1?	
How many times a week did you travel from home to Job 1?	

Please tick (✓) one box ONLY per line

How did you normally travel to Job 1?	Always	Usually	Occasionally	Never or rarely
By car				
By works or public transport				
By bicycle				
Walking				

JOB 2 *(if appropriate)*

Please complete EVERY line

Roughly how many miles was it from home to Job 2?	
How many times a week did you travel from home to Job 2?	

Please tick (✓) one box ONLY per line

How did you normally travel to Job 2?	Always	Usually	Occasionally	Never or rarely
By car				
By works or public transport				
By bicycle				
Walking				

Section C RECREATION

The following questions ask about how you spent your leisure time.

Please indicate how often you did each activity on average over the last 12 months.

For activities that are seasonal, e.g. cricket or mowing the lawn, please put the average frequency during the season when you did the activity.

Please indicate the average length of time that you spent doing the activity on each occasion.

EXAMPLE

If you had mowed the lawn every fortnight in the grass cutting season and took 1 hour and 10 minutes on each occasion.

If you went walking for pleasure for 40 minutes once a week.

You would complete the table below as follows:

Please give an answer for the AVERAGE TIME you spent on each activity and the NUMBER OF TIMES you did that activity in the past year.

EXAMPLE

	Number of times you did the activity in the last 12 months								Average time per episode	
	None	Less than once a month	Once a month	2 to 3 times a month	Once a week	2 to 3 times a week	4 to 5 times a week	Every day	Hours	Mins
Mowing the lawn				✓					1	10
Walking for pleasure					✓					40

Now please complete the table on pages 10 and 11

Please give an answer for the NUMBER OF TIMES you did the following activities in the last 12 months and the AVERAGE TIME you spent on each activity.

Please complete EACH line

	Number of times you did the activity in the last 12 months								Average time per episode	
	None	Less than once a month	Once a month	2 to 3 times a month	Once a week	2 to 3 times a week	4 to 5 times a week	6 times a week or more	Hours	Mins
Swimming — competitive										
Swimming — leisurely										
Backpacking or mountain climbing										
Walking for pleasure — you should not include walking as a means of transportation as this was included in Sections A & B										
Racing or rough terrain cycling										
Cycling for pleasure — you should not include cycling as a means of transportation										
Mowing the lawn — during the grass cutting season										
Watering the lawn or garden in the summer										
Digging, shovelling or chopping wood										
Weeding or pruning										
DIY e.g. carpentry, home or car maintenance										
High impact aerobics or step aerobics										
Other types of aerobics										
Exercises with weights										
Conditioning exercises e.g. using an exercise bike or rowing machine										

Please continue on the next page

Please complete EACH line

	Number of times you did the activity in the last 12 months								Average time per episode	
	None	Less than once a month	Once a month	2 to 3 times a month	Once a week	2 to 3 times a week	4 to 5 times a week	6 times a week or more	Hours	Mins
Floor exercises e.g. stretching, bending, keep fit or yoga										
Dancing e.g. ballroom or disco										
Competitive running										
Jogging										
Bowling — indoor, lawn or 10 pin										
Tennis or badminton										
Squash										
Table tennis										
Golf										
Football, rugby or hockey (during the season)										
Cricket (during the season)										
Rowing										
Netball, volleyball or basketball										
Fishing										
Horse-riding										
Snooker, billiards or darts										
Musical instrument playing or singing										
Ice-skating										
Sailing, wind-surfing or boating										
Martial arts, boxing or wrestling										

You have finished the questionnaire — *Thank you*